The electricity generation mix in Scotland: the long and windy road?*

Grant Allan[a], Peter McGregor[a] and Kim Swales[b]

[a] Fraser of Allander Institute, Department of Economics, University of Strathclyde
[b] Department of Economics, University of Strathclyde

1. Introduction

The mix of technologies used to generate electricity in Scotland has evolved over the last ninety years. Since 2000, there has been a rapid increase in renewables capacity and generation, particularly in onshore wind. This has been supported by UK and Scottish policy and the associated funding mechanisms, including the Renewable Obligations Certificates (ROCs). In the coming decade, the Scottish generation mix is likely to see unprecedented changes that will include significant investments in a range of new generation technologies.

Section 2 of this paper explains how the existing Scottish electricity generation mix was attained and Section 3 identifies the key drivers of changes over the next decade. Section 4 briefly examines some published scenarios for the Scottish generation mix and sets these in the context of the (recently updated) Scottish Government's targets for electricity generation. The scenarios are informed by recent technology-specific "roadmaps". Section 5 concludes by discussing the implications for policy.

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2. Development of the existing electricity generation mix in Scotland

Tables 1 and 2 show how the present operational electricity generation capacity in Scotland has developed through time. In Table 1, reading along the row for an individual technology identifies the decades in which the capacity (in MW) that is operational today was installed. Reading down a particular column in this table shows how much of the total present Scottish electricity generation capacity was installed in that decade. Similarly, each cell in Table 2 shows the number of separate facilities commissioned, by technology and decade. These two tables identify the evolution of the current Scottish electricity generation mix.

Table 1 shows the major periods of activity in terms of the existing generation mix in Scotland. Almost one-third of the present-day installed capacity was commissioned in the 1970s, with over 75% installed between the 1960s and 1980s. The 1990s saw only a fraction of the investment of earlier decades, with 65MW of new capacity commissioned, 63MW of which came from wind generation commissioned between 1995 and 1999. Table 1 reveals that of the 2,007MW of capacity commissioned since 2000, over 90% has come from renewable technologies, with most coming from onshore wind projects. During this period, 1,685MW of onshore wind capacity and 39 onshore wind projects have been installed.

At present, investment in renewables generation capacity is progressing more rapidly than the period immediately following the Second World War. That period saw the formation of the North Scotland Electricity Board and the generation of electricity from the water of the glens of Scotland using hydroelectric technologies (Hannah, 1982). These investments in the 1950s led to 791MW of capacity installed across 38 projects. Each of these individual hydro projects were part of larger schemes, such as the 262MW Sloy installation. The Sloy scheme comprised ten separate facilities with individual facilities coming into operation at different times between 1950 and 1963. The Great Glen scheme was similar in nature, with a total capacity of 225MW. The earliest of its constituent parts dates from 1955 and the most recent, an addition of 100MW to this scheme, from 2008.

Tables 1 and 2 also identify the development of major capacity in non-renewable facilities: the coal stations at Longannet and Cockenzie in the 1960s and 1970s, the gas station at Peterhead in the 1980s, and the nuclear facilities in the 1970s and 1980s. However, since 1990, almost 94% of the new capacity has been in renewable technologies, with much of this occurring since the year 2000.

Rather than the installed capacity for each technology, Table 3 gives the electricity (in GWh) generated by different technologies in 2009 (the most recent year for which data are available) and their respective share of total Scottish

Table 1: Capacity (in MW) of plants operational in Scotland in May 2010, by technology and decade of commission or initial generation

		1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	Total
Non-renewables	Coal	-	-	-	-	1,152	2,304	-	-	-	3,456
	Nuclear	-	-	-	-	-	860	1,205	-	-	2,065
	Gas/Oil	-	-	-	-	-	-	1,180	-	-	1,180
	Diesel	-	-	9	105	-	10	-	2	3	129
	Gas	-	-	-	-	-	-	-	-	123	123
Total non-renewable		-	-	9	105	1,152	3,174	2,385	2	126	6,953
Renewables	Wind (onshore)	-	-	-	-	-	-	-	63	1,685	1,748
	Hydro	17	186	-	791	173	-	2	-	130	1,299
	Pumped storage	-	-	-	-	440	300	-	-	-	740
	Biomass	-	-	-	-	-	-	-	-	44	44
	Poultry litter	-	-	-	-	-	-	-	-	12	12
	Wind (offshore)	-	-	-	-	-	-	-	-	10	10
Total renewables		17	186	-	791	613	300	2	63	1,881	3,853
	Total	17	186	9	896	1,765	3,474	2,387	65	2,007	10,806

Source: DECC, Digest of United Kingdom Energy Statistics, accessed September 2010

Table 2: Number of plants operational in Scotland in May 2010, by technology and decade of commission or initial generation

		1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	Total
Non-renewables	Coal	-	-	-	-	1	1	-	-	-	2
	Nuclear	-	-	-	-	-	1	1	-	-	2
	Gas/Oil	-	-	-	-	-	-	1	-	-	1
	Diesel	-	-	2	3	-	1	-	1	1	8
	Gas	-	-	-	-	-	-	-	-	1	1
Renewables	Wind (onshore)	-	-	-	-	-	-	-	4	39	43
	Hydro	2	7	-	38	14	-	1	-	11	73
	Pumped storage	-	-	-	-	1	1	-	-	-	2
	Biomass	-	-	-	-	-	-	-	-	1	1
	Poultry litter	-	-	-	-	-	-	-	-	1	1
	Wind (offshore)	-	-	-	-	-	-	-	-	1	1
	Total	2	7	2	41	16	4	3	5	55	135

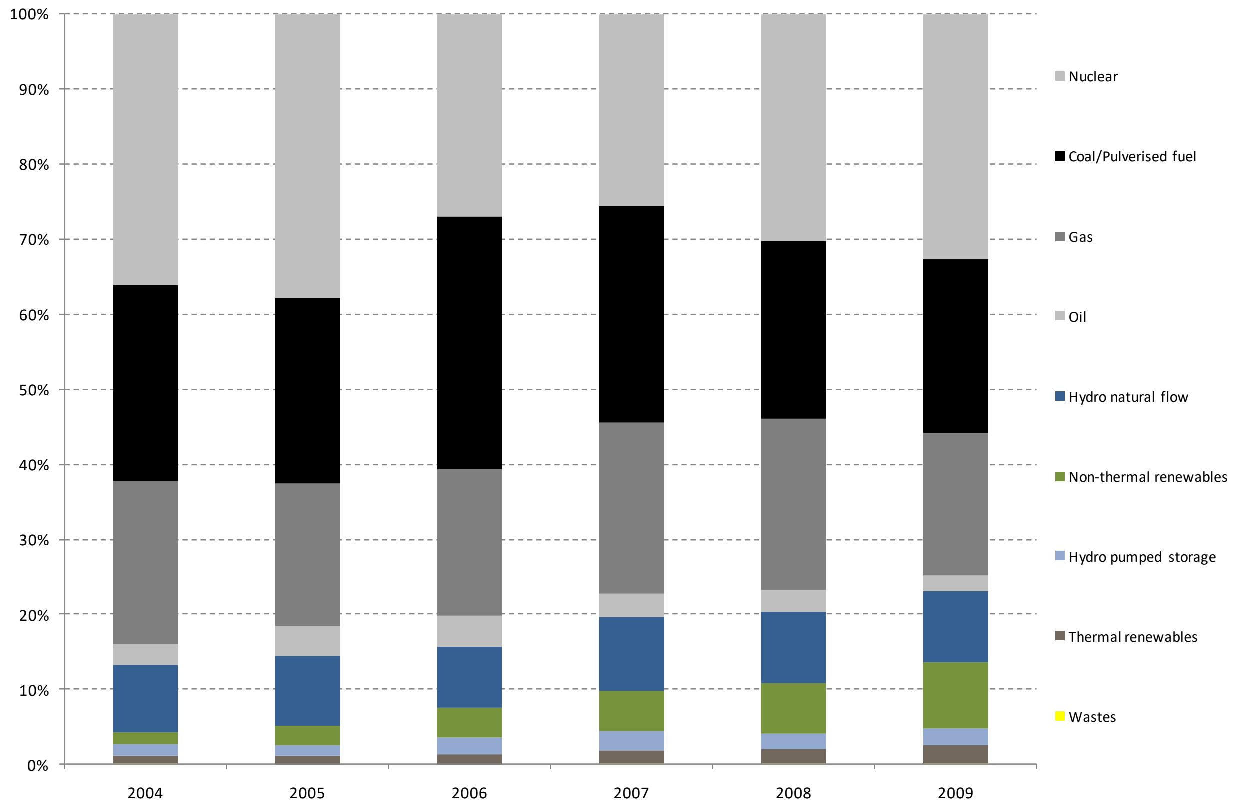
Source: DECC, Digest of United Kingdom Energy Statistics, accessed September 2010

Table 3: Generation in Scotland in 2009 by technology, GWh

	GWh	% share
Total from non-renewables	39,476	76.9
Nuclear	16,732	32.6
Coal / Pulverised fuel	11,965	23.3
Gas	9,690	18.9
Oil	1,089	2.1
Total from renewables	11,850	23.1
Hydro natural flow	4,877	9.5
Non-thermal renewables	4,558	8.9
Hydro pumped storage	1,087	2.1
Thermal renewables	1,310	2.6
Wastes	18	0.0
Total from renewables eligible under RO	8,185	15.9
Total, GWh	51,325	100.0

Source: DECC Energy Trends, December 2010. Note: Totals may not sum due to rounding.

Figure 1: Recent electricity generation in Scotland by technology, 2004-2008, % share of total generation



Source: DECC Energy Trends, various issues.

electricity generation in Scotland. Total generation was 51,325 GWh. Approximately 23% comes from renewable technologies. Note that this is significantly lower than renewables share of installed capacity in Scotland due to the lower capacity factors of these technologies. Nuclear contributes the largest share (over 30%) and coal (23%) and gas (19%) produced significant shares. Figure 1 shows, for the same technologies identified in Table 3, how the contribution of each technology to total electricity generation in Scotland has changed between 2004 and 2009.

Table 4 identifies where the electricity generated in each of the countries of the UK was actually consumed in 2009.

Table 4: Production and consumption of electricity by region of UK, 2009, GWh

		UK region of generation				ROE imports	
		England	**Scotland**	**Northern Ireland**	**Wales**		**Total consumption**
A	Generators own use	12578	3792	119	4828		21317
B	England	249051	10209		8287	3228	270775
C	Scotland		33010				33010
D	Northern Ireland		1937	6836			8773
E	Wales				17740		17740
F	ROE exports			367			367
G	Transmission losses	4838	584	156	315		5893
H	Distribution losses	17615	1793	548	1061		21017
A+B+C+D+E+F+G+H	Total generation	284082	51325	8026	32231	3228	378892

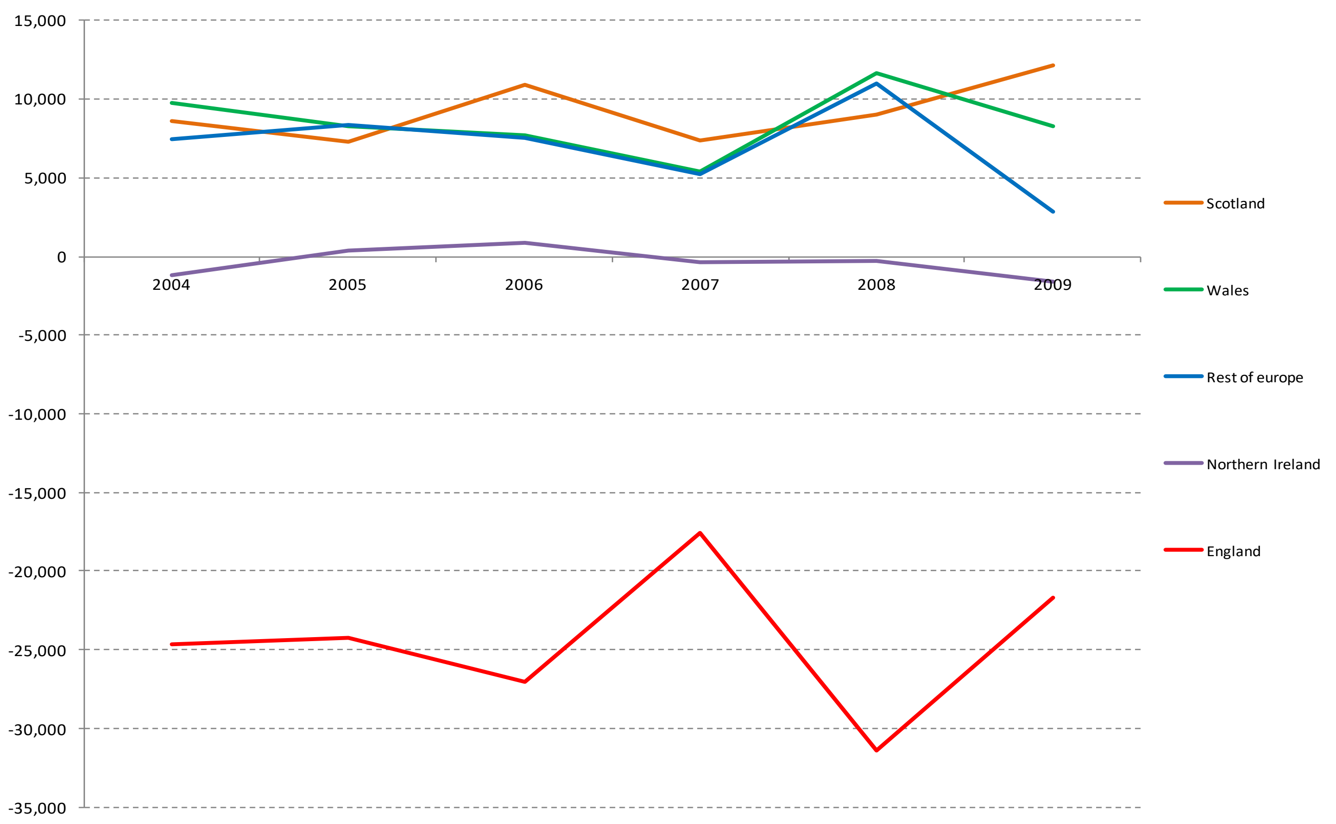
Source: DECC Energy Trends, December 2010, and authors calculations. Totals may not sum due to rounding.

Both Scotland and Wales were net exporters of electricity in this year, exporting 23.7% and 25.7% of net electricity generated in each region respectively. Northern Ireland was a net importer of electricity, with imports from Scotland greater than its exports to the rest of Europe. The 500MW Moyle interconnector between Scotland and Northern Ireland – which opened in 2002 – is currently a net exporting route for Scottish electricity. Scottish electricity generation also contributes to electricity consumed in England. Note that these figures refer to net exports over the year, and not half-hourly flows, where the regional pattern of generation and use could be quite different.

Reading along row B, for example, we see that of the 270,775GWh of electricity consumption in 2009 in England, just almost 92% was met by English generation with the rest coming from imports from Scotland (3.8%), Wales (3.1%) and the Rest of Europe (1.2%). For Northern Ireland, the pattern was quite different, with net exports to the rest of Europe corresponding to 4.6% of total generation, and net imports from Scotland making up 22.1% of total use.

Figure 2 shows how the regional trade in electricity has changed between 2004 and 2009. On the vertical axis is the difference between annual regional exports and imports of electricity to regions of the UK (in GWh). While Northern Ireland has small net imports and exports (in absolute terms) over the five years, we can see that significant net imports by England (equivalent to between 6.1% and 10.7% of annual electricity consumption in that region) are provided by exports from Scotland, Wales and the rest of Europe.

Figure 2: Net exports of electricity by region of UK, 2004 to 2009, GWh



Source: DECC Energy Trends, various years.

3. Factors affecting the future electricity generation mix in Scotland

Several interconnected factors are likely to produce significant changes in the future capacity and electricity generation mix in Scotland. These are due to two broad types of factors: technical and policy.

There are two key technical factors that are important influences on the way in which electricity is generated in Scotland. One is developments in the network and the grid. The second is the remaining lifetimes of existing plant. We attempt to summarise these issues here, beginning with the electricity transmission system. It has been acknowledged that significant reinvestment will be necessary over the next twenty years if renewable energy sources, typically located in areas away from major centres of demand, are to meet the levels of envisioned penetration (Royal Society of Edinburgh, 2006; Forum for Renewable Energy Development in Scotland: Marine Energy Group, 2009). ENSG (2009) gives details of the types of grid investments required under alternative scenarios. It has been argued that substantial upgrades are needed to Scotland's electricity transmission system, and that this will depend on the level of renewable capacity. A recent estimate suggested that a programme of network investment in the (UK) transmission grid totalling £4.86 billion will be required (ENSG, 2009). Such grid enhancements include plans to increase the capacity of interconnection between Scotland and England through subsea HVDC cables to complement the existing onshore connection. Such transmission grid investments, however, require the permission of the networks regulator (OFGEM), which then allows the grid owner to recoup the costs of investment from generation customers who use the network, plus a (regulated) return on their investment. The regulator therefore predicts the extent to which network extensions would be used before it grants permission. But generators will not be willing to contract to site facilities in places served by the new grid until the new grid investment is made. This explains some of the delays in bringing forward additional generation in areas currently not served by the transmission network, and also emphasises the importance of developing an appropriate network for delivering the energy goals set by Scotland and the UK.

Concerning the lifetime of existing plants, the two major coal power stations in Scotland are now covered by the European Union Large Combustion Plant Directive. From 2011 they will have to stop production after 10,000 additional hours of operation, or at the end of December 2015, whichever is sooner. At the time of writing, Scottish Power – the operator of Cockenzie – is consulting on replacing the coal station with a Combined Cycle Gas Turbine (CCGT) station, together with the associated infrastructure. Coal stations may remain in Scotland in the long term with the use of Carbon Capture and Storage (CCS) technologies, such that the vast majority of their emissions are prevented from entering the atmosphere by being buried in previously depleted gas fields. Such storage capacity exists in the North Sea (Scottish Centre for Carbon Storage, 2009a) and it is hoped that CCS technologies might play a role in the future of coal generation in Scotland and the UK, although no full demonstration-scale plant has been completed. A prototype Carbon Capture unit is undergoing testing at Longannet coal power station. There are EU plans for 10-15 demonstration projects for CCS to be operational by 2015, although widespread deployment of CCS technologies is not expected to occur until 2020 (Scottish Centre for Carbon Storage, 2009b).

Table 5: Renewable energy developments in Scotland at stages prior to operation stage, as of 10th September 2010, MW

Technology	Under construction	Resolution to consent	In planning	In appeal	In scoping	SRO outstanding	Total
Hydroa	103.40	24.65	19.02	0.00	20.83	5.49	173.39
Onshore wind	431.05	2,832.18	3,593.28	811.60	2,610.31	4.31b	10,282.73
Offshore wind	0.00	0.00	0.00	0.00	115.00	4.31b	119.31
Energy from waste	2.73	21.30	4.27	0.00	5.80	40.46	74.56
Biomass electricity	13.70	98.80	39.00	0.00	566.00	12.90	730.40
Biomass heat	6.40	155.00	34.32	0.00	25.00	0.00	220.72
Wave	0.00	7.00	0.00	0.00	600.00	0.00	607.00
Tidal	1.00	0.00	10.00	0.00	632.00	0.00	643.00
Total	558.28	3,138.93	3,699.89	811.60	4,574.94	67.47	12,851.11

Notes: a = excludes pumped hydro, b = total wind capacity with SRO outstanding is 8.62MW, but no disaggregation by On- or Offshore are provided in source. We have split this between On- and Offshore wind 50:50. Source: Scottish Renewables (2010)

Of the current operational nuclear plants in Scotland Hunterston B was opened in 1976 and Torness in 1988. These plants are now reaching the end of their design lives, and are scheduled for closure in 2016 and 2023 respectively (RSE, 2006). In both cases, plant lifetime extensions are possible and would typically increase the working life of each plant by around 5 years. The recent report by a committee of members of the Scottish Parliament (2009) indicated that, while it did not see a new generation of nuclear facilities as necessary, "there will be a need to extend the operating lifetimes of the current generation of nuclear power stations in Scotland" (Scottish Parliament, 2009, paragraph 144). This is to avoid the perceived "energy gap" caused by the loss of existing coal and nuclear facilities.

As well as these environmental regulations, oil and gas generation will be affected significantly by the increasing level and volatility of fuel prices. Indeed, in the case of both forms of generation, the marginal cost of production will be a function of the prevailing fuel price (subject to any fuel contracts). For the period to 2020 and beyond, fuel prices are expected to rise (van Ruijven and van Vuuren, 2009). This reflects current concerns about resource depletion (e.g.

see de Almeida and Silva, 2009), reduced investment, greater demand (and uncertainty), and geopolitical risks. The range of fuel price forecasts is often huge and higher oil prices have been predicted before (for example, Saunders, 1984).

The main factors affecting the shape of energy policy in Scotland have been discussed elsewhere (Allan et al, 2008). Of course, EU and UK energy policies will continue to exert significant impacts on the Scottish generation mix. For example, the efficacy of the EU ETS in establishing a credible long-term carbon price is of crucial importance in correcting for the pollution externalities embodied in fossil fuel generation. We return to the role of the EU ETS in Section 5. Here we briefly summarise relevant aspects of Scottish (and UK) energy policies. Since devolution in 1999, electricity generation in Scotland has increasingly become a concern of the Scottish Government, despite energy being an issue that is reserved to Westminster. The Scottish Government has set ambitious targets for the share of Scottish electricity that comes from renewable sources. Its previous target was for 50% of gross electricity consumed in Scotland to come from renewable sources by 2020, with an interim target of 31% in 2011. During the writing of this paper, the Scottish Government announced that it would be increasing its 2020 target to 80%. It is not clear if any new interim targets will be set.

As of 2009 (the most recent year for which data are available) renewable electricity generated in Scotland was 23.1% of Scottish generation. It can be verified from Table 4 that for Scotland, total electricity generation less transfers equalled 39,179 GWh (i.e. total generation (the final row) less exports to England (row B) and Northern Ireland (row D)), while from Table 3, the amount of renewable generation in 2008 was 10,745 GWh (this is the sum of generation from “Hydro flow”, “Non-thermal renewables” and “Thermal renewables”). Renewable electricity generated in Scotland as a share of Scottish generation minus transfers was therefore 27.4% in 2009. We note that the existence of an electricity grid covering Great Britain (plus an interconnector between Scotland and Northern Ireland) means that there is no need for Scottish demand to be limited to Scottish generation. With regards to nuclear, the Scottish Government has stated that future applications for the building of new nuclear stations are likely to be rejected, a position backed in a vote in the Scottish Parliament[1]. Depending on circumstances, however, Scotland could be in a position of importing electricity from a GB grid which could have been produced in nuclear facilities in England (although the scenarios considered in the next section all envisage Scotland continuing to be a net electricity exporter up to 2020).

Renewable electricity in the UK (including Scotland) is supported through the Renewables Obligation (RO), which requires electricity supply companies to provide Renewables Obligations Certificates (ROCs) to the electricity regulator (OFGEM). The number of certificates that must be produced is currently equivalent to 4.27 ROCS per 100 MWh supplied in 2010/11), and the UK Government intends that the ROC support will remain until 2037. These certificates are earned by accredited generators for each MWh generated using renewable energy sources. They can be sold in the ROC market, with generators on the supply side, and electricity retail companies on the demand side. The price of ROCs in theory is restrained by the provision of an alternative method by which supply companies can meet their obligation, paying a buyout price, which began at £30 per MWh in 2001 and rises in line with the Retail Price Index every year. In 2009/10 the buyout price was £37.19.

Monies received by OFGEM from supply companies paying the buyout price for any ROCs they are unable to produce are redistributed back to electricity supply companies, whose share of the total redistributed buyout fund is in proportion to their contribution to the total number of ROCs received. In practice, this has meant that since inception the annual value of a ROC has been between 20% and 50% higher than the buyout price, producing an important stimulus to renewable energy development (as seen from the growth in renewable capacity between 2000 and 2009 in Tables 1 and 2).

From April 2009, the UK government introduced “banded” ROCs, whereby accredited renewable electricity generators receive different quantities of ROCs for each MWh they produce, depending on the technology used to generate each MWh. In this way, the support for renewables is no longer “technology-blind”, but is intended to bring forward developments in generation technologies other than onshore wind. The Scottish Government has introduced further differentiation, designed to favour new marine technologies. This began with the Marine Supply Obligation, which was superseded by the banded ROCs for wave and tidal stream in April 2009. Under the banded ROCs, each generator using wave technologies to generate electricity receives 5 ROCs per MWh, while tidal technologies receive 3 ROCs per MWh[2].

Along with ROC banding, other measures underline the Scottish Government’s support for marine technologies. These measures include the EMEC testing site on Orkney, the £13 million Wave and Tidal Energy Scheme[3] (WATES) funding for testing devices in Scottish waters, and the £10 million Saltire Prize challenge[4]. These initiatives underline the intention of Scottish Government to ensure that renewables development in the next ten years is not limited to as narrow a range of technologies (predominately onshore wind) as has been the case until now.

Table 5 identifies the capacity of renewable energy projects in Scotland, by technology, at pre-operational stage. This includes projects without planning permission, which are those indentified in the stages other than “Under construction” in Table 5. Even assuming that not all projects are granted permission, there is demand from generators to install renewable energy capacity in Scotland. Over 80% of the capacity of the proposed projects relates to Onshore wind, which is likely to provide the bulk of new renewable energy developments up to 2020. Thus, existing renewable electricity generation plans suggest that a balanced portfolio of renewable technologies will not be delivered.

It is interesting to note that in the year since September 2009 the total capacity of pre-operational renewable energy developments increased by over 1,500MW. This is largely due to the increase in Biomass heat (up 149.16MW), Biomass electricity (up 172.2MW) and significant increases in the amount of Wave and Tidal capacity at the "Scoping" stage (up 600MW and 570MW respectively).

Previous work (Allan et al, 2010a) has identified the UK's recent Feed-in Tariff (FiT) scheme (DECC, 2010) as the "most significant recent policy initiative" in stimulating the penetration of distributed generation technologies. For installations under 5MW this measure replaces the Low Carbon Building Programme and the Renewable Obligation. Under this scheme, licensed electricity suppliers are required to pay a tariff to small scale low-carbon generators for electricity generation[5], and an additional export tariff when the electricity is exported to the grid. These tariffs apply for the operational lifetime of the device. By obliging electricity suppliers to purchase renewable electricity from suppliers at a favourable price, the FiTs policy provides emerging renewable technologies an opportunity to compete in the electricity market. The policy is intended to increase the uptake of small-scale low carbon technologies by increasing their attractiveness for households and communities.

The FiTs are scaled according to technology, and payments are scheduled to gradually fall over time, so as to produce incentives for cost-cutting and efficiency measures in renewable electricity industries. The idea behind gradual tariff reductions is that as demand for small-scale renewable devices grows, manufacturers can take advantage of economies of scale, price reductions are passed onto the consumer, and the industry becomes competitive on its own. In the UK, there are indications that FiTs are viewed as potentially profitable opportunities, with utility companies financing solar installations in housing developments and schools (Solar Power Portal, 2010), and the FiT scheme is likely to remain a future stimulant to investment in renewable energy devices by utilities and local authorities, as well as private investors.

4. Scenarios for Scotland's future electricity generating mix

4.1 Scenarios from 2008 and 2009

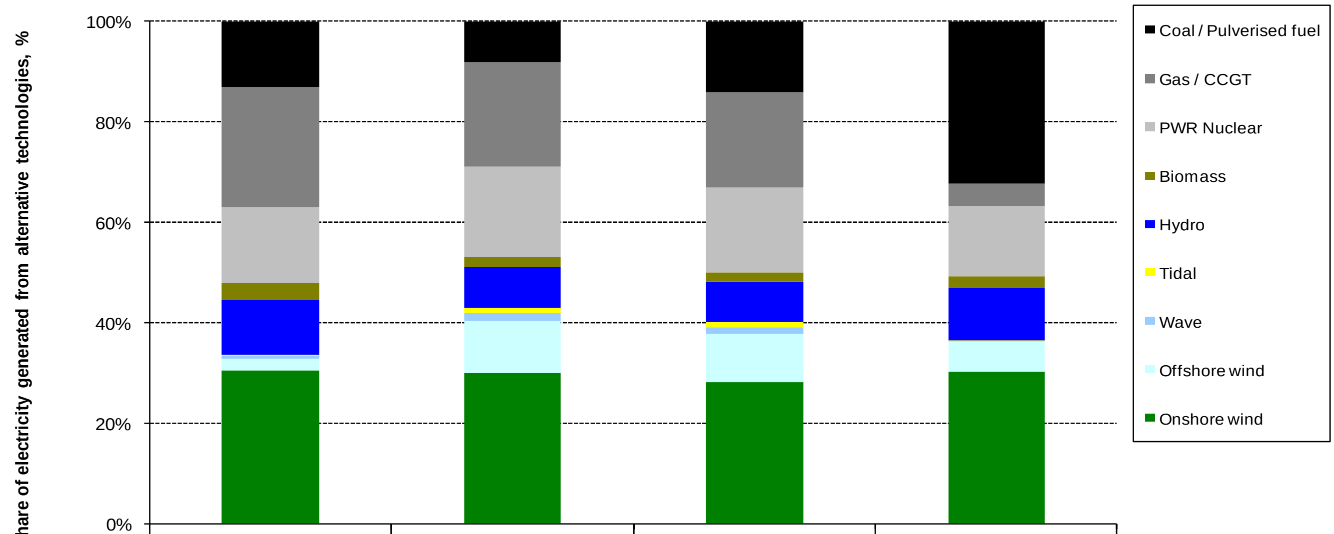
We study three projections from 2008/9 of the Scottish electricity generation mix for Scotland in 2020. Two of these are produced by the private sector (SCDI, 2008; Murray, 2009[6]), while the third comes primarily from a recent Scottish Government document "Scottish Energy Study" (AEA Technology, 2008). In this third study there are two alternative scenarios, configured on "Central" and "High" assumptions regarding the future of primary energy prices. In total therefore we have four scenarios. For ease of exposition, we label these four scenarios the following: SCDI, Murray, and SES1 and SES2, respectively.

All four scenarios focus on the same year, 2020, and have a number of other similarities. First, the total of Scottish electricity demands are broadly similar across all the scenarios. The SCDI scenario predicts annual increases between 2008 and 2014 of 0.9%, reduced to 0.4% per annum for 2016 to 2020. The Scottish consumption in this scenario for 2020 is 45.9TWh, 9% higher than demand in 2008. Murray follows the assumptions in SCDI. However having been published six months later, this report is able to reflect the experiences of early 2009 when economic output and energy consumption fell in Scotland. The Murray (2009) study therefore assumes no growth in electricity demand between 2008 and 2009, then the same pattern of demand growth as SCDI between 2009 and 2020. This gives total Scottish electricity demand in 2020 of 45.4TWh. Total demand for electricity (including losses and own use) in Scotland according to the SES1 scenario will be 41.5TWh, and 42.5TWh in the SES2 scenario. These are both actually slightly lower than demand in 2005 and are therefore around 9% lower than the other scenarios.

Second, given the significant uncertainty surrounding some of the anticipated developments discussed in Section 2, it is perhaps somewhat surprising that the installed capacity and total amount of electricity generated in Scotland in 2020 remains broadly the same across the four scenarios. The SCDI scenario predicts generation of 53.4TWh in 2020, coming from an installed capacity of 15.9GW. The Murray report predicts a slightly higher level of generation of 58.0TWh with a correspondingly higher installed capacity of 16.5GW. As with consumption, total generation is lower in both of the AEA Technology scenarios. The SES1 and SES2 scenarios, have total generation of 50.3TWh and 54.3TWh respectively. While there are no capacity figures given for the SES1 and SES2 scenarios, both see large increases in the extent to which renewable generation technologies provide electricity to the generation mix. There is also the continuation of some nuclear (at least through 2020), a move towards "clean coal" and the replacement of some new gas capacity. These figures suggest that the total capacity for generation in Scotland would be significantly higher than current levels, particularly given the lower capacity factors expected for onshore wind, which other commentators expect to produce much of the growth in renewables.

We can see from the projected levels of generation and demand in Scotland in 2020 that in all four scenarios Scotland is forecast to remain, as now, a large net exporter of electricity to the rest of the UK (i.e. its local consumption is significantly less than its local generation). However, each of the scenarios anticipates a different development path for generation technologies, which give us four alternative

Figure 3: Generation mixes in each of the four 2008/2009 scenarios



	SCDI (2008)	Scottish Energy Study 1 (2009)	Scottish Energy Study 2 (2009)	Murray (2009)
Total capacity	15.9GW	-	-	16.5GW
Total generation	53.4TWh	50.3TWh	54.3TWh	58.0TWh
Scottish demand	45.9TWh	41.5TWh	42.5TWh	45.4TWh

generation mixes for Scotland in 2020. These generation mixes are displayed in Figure 3.

Consider first the share from renewable technologies. In each of the scenarios there is a significant increase in generation from renewable sources for the reasons already discussed. The lowest renewable share in generation comes from the SCDI scenario with 48%, while the highest share comes from SES1 scenario is 53%. Within renewable technologies, Onshore wind provides most of the renewable generation (and around 30% of the total generation), a feature which is common across all scenarios, while Hydro provides around 10% of total generation. The remainder of renewable generation is assumed to come from a range of Biomass, Offshore wind and Wave and Tidal technologies. Offshore wind contributes, in all scenarios apart from SCDI (where biomass provides 3.4%), the third highest share of renewable generation.

It is in non-renewable technologies that the largest differences are seen across the scenarios. Whilst nuclear is expected to provide between 14% and 18% of total generation, the share of coal and gas in the total generation mix does differ more radically, particularly so in the GH scenario where the mix is heavily in favour of coal generation, rather than gas, while in the other scenarios the opposite is the case.

With regards to the specific technology scenarios, a number of renewable technologies have been studied by the Forum for Renewable Energy Development in Scotland (FREDS), a group established by the Scottish Executive. Their report in 2005 (FREDS, 2005), estimated that the previous target of 40% of electricity generated from renewable sources was consistent with an installed renewable capacity of 6GW. Table 1 above shows that, as of May 2010, renewable electricity generation capacity in Scotland is 3.85GW. The higher target for renewable electricity generation described above would therefore suggest a higher installed renewable capacity.

On the specific renewable technologies, the report notes that while onshore wind is likely to provide much of the new renewable capacity, "assuming a range of technical and economic issues can be overcome, other technologies should also be capable of playing an important part by 2020" (FREDS, 2005, p. 11). That same report noted that an estimated wave and tidal practicable resource off Scotland was around 1300MW installed capacity. The most recent study of the wave and tidal resource in Scotland (FREDS: MEG, 2009), illustrated three possible deployment path scenarios for marine capacity – ranging from 500MW to 2000MW by 2020.

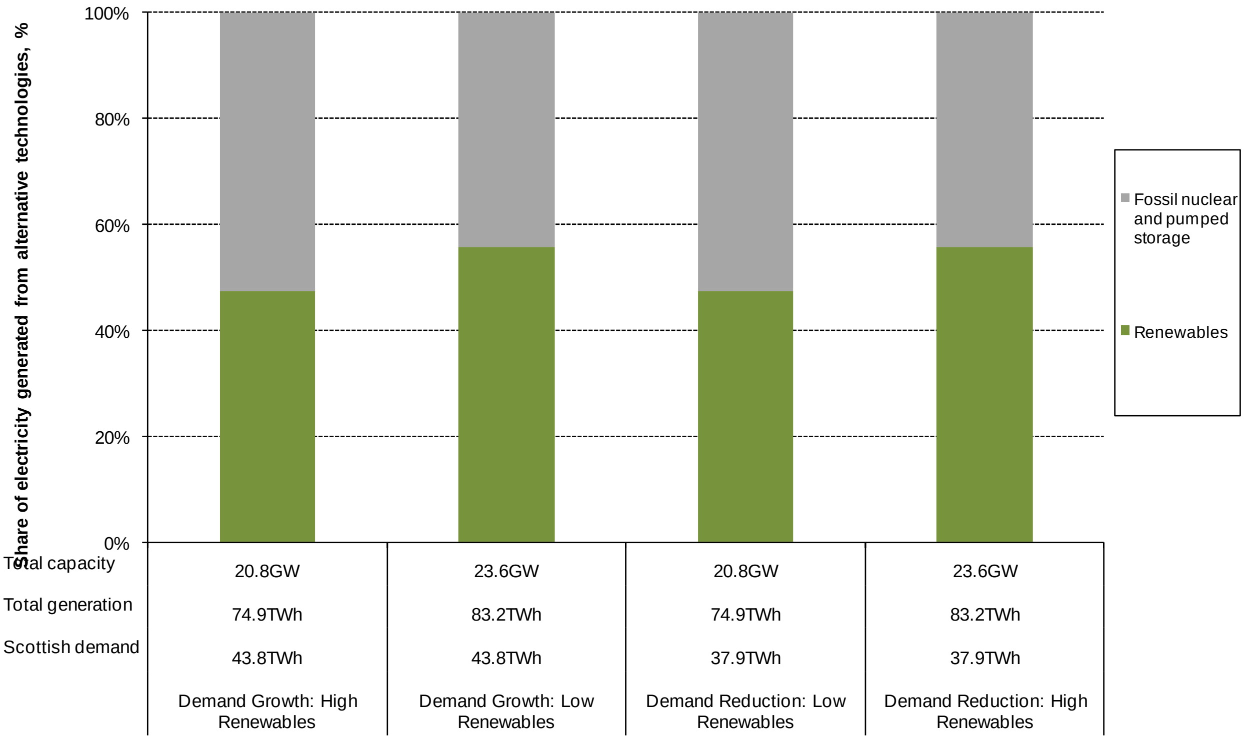
4.2 Scenarios from 2010

As this paper was in preparation, Scottish Renewables published commissioned work produced by Garrad Hassan (2010). This coincided with the announcement that the Scottish Government's target for renewable electricity would increase from 50% by 2020 to 80% by that same year. Their report details four scenarios, also for 2020, in which this figure is exceeded. The four scenarios combine two in which demand is lower, two in which demand is higher, and in each of these four cases, there is either “high” or “low” renewable development.

These results are shown graphically in Figure 4. The publication does not identify the contribution to Scottish electricity generation from individual technologies. We are therefore unable to disaggregate by technology as in Figure 3. This report shows how even within a short period of time, the future shape of the electricity generation mix in Scotland is predicted to be radically different from a few years previous. Note, for example, the huge differences in the capacity figures between Figures 3 and 4. Scottish demand estimates are broadly comparable, as is the broad pattern of electricity generation. The larger capacities shown in Figure 4 account for the significant increase in the ratio between electricity generated from renewable sources in Scotland and Scottish electricity consumption.

Further, considering the Scottish electricity generation mix explicitly as a portfolio, implies a rather different perspective that simply considering the individual technologies within that portfolio. As is shown in Allan et al (2010c), renewable technologies, including wave and tidal stream, can help to reduce the price variability of an electricity mix largely due to their zero correlation with the price of fuel inputs. In that paper we find that increasing the share of renewables in the Scottish generation mix can allow the cost variability of electricity to be reduced without any increase in the overall electricity price.

Figure 4: Generation mixes in each of the four Garrad Hassan (2010) scenarios



5. Conclusions

The Scottish electricity generation mix has seen radical change over the last decade. It has been transformed by a rapid development of renewable energy capacity, largely coming from onshore wind. Moreover, it is likely that over the next decade, for both technical and policy reasons, the electricity mix will change as never before. Strong support for alternative renewable technologies such as offshore wind, wave and tidal is likely to bring new capacity in these technologies –. Similarly, decisions taken about non-renewable technologies will be crucial for the future shape of the Scottish generation mix. With electricity demands likely to continue to increase over time, meeting these from a portfolio of generation technologies would be one way by which the energy policy goals of energy security, reduced environmental damage and enhanced economic development could be stimulated.

We note, however, that the EU Emissions Trading Scheme (EU ETS) deals with the allocation of the right to pollute across the EU. The rationale for Scottish Government ambitions for renewables therefore should be seen in light of this. By being members of the EU ETS, Scotland's targets for the sectors "covered" by this mechanism (which includes the energy sectors) are met.

Accordingly, renewables policy does not directly assist the achievement of (domestically set) emissions reductions targets. Against this background, renewables must be regarded as contributing to the other goals of energy policy, such as security and supply and economic development through new low carbon technologies. This would be consistent with energy, particularly renewables, being a "key sector" in the Scottish Governments Economic Strategy (Scottish Government, 2007). See McGregor et al (2010) elsewhere in this special issue for more discussion of the relative roles played by legislation in Scottish climate change policy.

Recent work (e.g. Allan et al, 2008b, Gilmartin et al, 2010) has begun to quantify the potential for Scottish and UK economies respectively to be stimulated by renewable energy development, and the exporting of knowledge and technical components to service this expanding industry. This highlights, among other things, that the next decade could be crucial for Scotland capturing a significant share of a worldwide market for renewable technologies, with all the knock-on benefits to the Scottish economy.

The Scottish generation mix has evolved over the last ninety years through the development of hydropower from the glens, coal and nuclear facilities around the coasts, and the recent surge in onshore wind development, now beginning to move offshore. Further radical change seems likely in the next decade offering both significant risks and opportunities for Scotland.

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Endnotes

[1]Although, strictly, the Scottish Government is required to consider each application to build a new nuclear facility in Scotland on its own merits.

[2]The impact of these proposals on the levelised costs of wave and tidal electricity is discussed in Allan *et al* (2010b).

[3]As of September 2009, £2.946 million had been spent on WATES projects and their associated infrastructure for testing. It is anticipated that all the £13 million will be spent by March 2011.

[4]The details of the prize are the following. "£10 million will be awarded to the team that can demonstrate in Scottish waters a commercially viable wave or tidal energy technology that achieves a minimum electrical output of 100 GWh over a continuous 2 year period using only the power of the sea and is judged to be the best overall technology after consideration of cost, environmental sustainability and safety" (Scottish Government, 2008). The prize is intended to be awarded in Spring 2015, following the assessment of qualifying marine generation between January 2010 and December 2014.

[5]Regardless of whether the electricity generated is exported to the national grid.

[6]The private sector study (Murray, 2009) was based on research prepared by Garrad Hassan.